usual and that the proportion of organic matter was considerably more than average. Minerals, loess, spores, plant-hairs, bits of decayed matter, glass, and transparent crystals were readily isolated and detected.

A flat beaker was placed on the roof of the solar radiation observatory at noon of the 11th, and taken down 24 hours later. Mr. M. E. Jefferson, of the Bureau of Chemistry and Soils, kindly consented to make a petrographic analysis of the contents of this beaker and his results are quoted herewith:

NOTE ON THE PETROLOGY OF THE DISTRICT OF COLUMBIA DUST STORM OF MAY 11, 1934

In connection with the observations on the dust storm discussed in the preceding paper, a sample of the dust was collected by Mr. I. F. Hand in an open beaker which was set out early on the 11th and taken in on the 12th at noon when the dust had practically disappeared from the air. The sample was examined under the petrographic microscope by immersion in the usual oils.

Quartz and gypsum were present in amounts great enough to be readily identified, while calcite was found in very small amounts in the form of small size particles. Orthoclase and microcline were identified and apparently showed no alterations. Quartz and feldspar were found to be clear and unstained. Mica was present but appeared altered at the edges to such an extent that identification was impracticable. It is apparently muscovite and biotite.

There was considerable isotropic material in the sample, none of which, however, could be definitely classified. Conchodial fragments had indices ranging from 1.45 to 1.60 and a few flat irregular fragments had less than 1.43, usually low.

The volcanic glass, hornblende, zircon, and tourmaline found by Alexander (4) in the Buffalo dustfall were not identified as such here.

Measurement of the particle size gave the range of diameter or length 0.001 mm to 0.13 mm with most of the mineral constituents in the range 0.005 to 0.04 mm. Winchell and Miller (5) found the range in the Madison dustfall to be 0.003 to 0.1 mm the quartz and feldspar in this case were stained with limonite and hematite. In the Buffalo storm Alexander reports lengths up to 0.05 mm. There is considerable opaque material of rather large particle size (0.01 to 0.1 mm) which we have made no attempt to identify.

The organic material present in this dust storm is much greater than that given by Alexander being at least 30 percent and consists of spores, stellate plant hairs, and vegetable fibers. No attempt was made to classify the spores and plant hair present. In several tests diatoms were recognized.

Dr. Charles F. Brooks, Director, Blue Hill Meteorological Observatory, Harvard University, Hyde Park, Mass., transmits the following note from C. A. Chapman:

DUST FROM CIRCULAR GLASS PLATE 25 CM IN DIAMETER AT MOUNT WASHINGTON, MAY 11 AFTER EXPOSURE ALL DAY

Amount of dust on the plate —— 0.011 —— grams.

The dust is very fine and varies from 5–30 microns in diameter. The average grain size is 10 microns.

For the most part the individual particles are decidedly angular and show no signs of frosting.

The dust consists principally of quartz and feldspar which exist as clear colorless grains.

Several species of diatoms are present but no attempt was made to identify any of them. They occur as small, porous, plant-like forms.

Other minerals identified as occurring in small amounts were sericite, green chlorite, iron oxides, and several aggregate masses of very fine-grained amorphous material.

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HOW A COMMERCIAL PILOT MAY CONTRIBUTE TO A PROGRAM OF AIR-MASS ANALYSIS BY OBSERVATIONS MADE DURING FLIGHT

By L. P. HARRISON

[Weather Bureau, Washington, D.C.]

The need for analyzing weather as a three-dimensional system rather than merely as a two-dimensional one, such as is exemplified by the customary synoptic charts, has, among other things, brought about the regular daily use of airplane observations to heights of 17,000 feet or over as a permanent adjunct of the weather service. The planes now employed in this service are few in comparison with those in commercial use, hence there exists the possibility of securing a valuable addition to the scheduled soundings by enlisting the aid of commercial air pilots to record and make available meteorological observations made during their flights over the airways, just as many years ago the aid of mariners was enlisted for the collection of meteorological observations made on commercial vessels plying the trade routes of the Seven Seas.

In requesting the cooperation of pilots for the development of a program along this line, we should ask them to make their observations from the viewpoint which has contributed most to modern meterology, viz, physical weather analysis and air-mass analysis. However, before we may detail the character of the observations desired, we must first make clear just what we mean by these terms.

The fundamental concept of this method of analysis is based on the realization that our weather is caused, in general, by the expenditure and transformation of stored atmospheric energy (gravitational potential, and thermal) with the attendant interplay between air masses of markedly contrasting temperatures which have come into juxtaposition after having moved away from different respective regions over which they have recently been at rest, or wandering for a length of time sufficient to permit the environments to bring them to a state in regard to temperature, moisture content, and other features, more or less typical of these regions for the given time of year. The individual air masses do not freely mix with one another but tend to remain separate with more or less sharply defined boundary surfaces, or surfaces of discontinuity between them. Not infrequently, if not ordinarily, it is found that relatively thin transition zones serve instead of distinctly marked surfaces of discontinuity. Usually, rather marked changes in the characteristics of the respective air masses are observable as one crosses a surface of discontinuity, for the air masses on their travels tend to retain the characteristics of temperature, moisture content, and other properties which are normal for the regions from which they originated. However, the varied physiographic and other conditions along the course over which the body of air has traversed exert a profound modifying influence upon these characteristics, especially upon those in its lower portion. The formation of any of the forms of moisture condensation within the air mass, or their precipitation through it, likewise produce therein important deviations from the original distinguishing traits.

The surfaces of discontinuity we have already referred to are of great significance in air-mass analysis since, besides delimiting the extent of the air masses and their subdivisions, they frequently represent the loci wherein the transformation of energy, potential or latent, is initiated. If one were to make a series of airplane ascents periodically at a given locality, carrying suitable meteorological instruments, he would discover the atmosphere to be stratified and would observe the heights of the surfaces of discontinuity between the strata to be gradually becoming greater or less. Moreover, he would sometimes find that the distinctive meteorological qualities within each of the strata might be changing gradually as the latter moved bodily along with the wind; however, this is not necessary since not infrequently the air masses closely approximate to horizontal homogeneity in respect to these qualities. Since the surfaces of discontinuity are not level in general, some of them must intersect the surface of the earth. Where this occurs we have the phenomenon known as a "front", the passage of which over a place is attended ordinarily by well-marked changes in conditions of temperature, wind, etc.

With this very general statement of the immediate causes of our weather, we do not commit ourselves too specifically as to the details of the mechanism of the cyclone and anticyclone, but leave to the future the settlement of these questions.

At this point we may indicate the position that air-mass analysis holds among the principal steps leading up to and including forecasting of the weather. This may perhaps best be done by means of a synopsis such as the following:

1. *Weather observation.*—The observing of meteorological phenomena and the noting of data representing them.

2. *Physical weather analysis.*—A physical analysis of the state of the atmosphere and the activities going on within it. This consists of two parts:

(*a*) *Air-mass analysis.*—Identification and delimitation of air masses, that is, analysis of the magnitudes and distribution of characteristic properties and other significant meteorological elements of the air masses; classification of the air masses according to source-region and principal modifications due to trajectory over land and water surfaces; and determination of the position, structure, nature, etc., of the various fronts and surfaces of discontinuity (zones and layers of transition) or boundaries of the air masses.

(*b*) *Dynamical weather analysis.*—Analysis or diagnosis of the physical activities underlying given weather conditions, that is, a study of present and past weather situations to describe the nature of the activities, such as precipitation, cloudiness, definite relative motions of adjacent air masses, etc., which are occurring in the given weather situation and to determine the physical causes which are bringing and have brought these activities about.

In short, air-mass analysis is the determination of what air masses are present, how they are characterized, and where they are. Dynamical weather analysis is the determination of what the air-masses are doing and why they are doing it.

3. *Weather prediction.*—Forecasting the state of the weather at some future time on the basis of present and past weather situations.

(*a*) *Synoptic projection.*—The projection of the present and past configurations of air masses, pressure systems, etc., into the future, allowing for the nature, magnitudes, and distribution of the air masses, forces, etc., which are operating, and for any changes which may occur with place and time as a result of the various factors involved.

(*b*) *Dynamical weather projection.*—The projection from present and past configurations of air masses, pressure systems, weather conditions, activities, etc., into the future, and then the indication or description of the meteorological activities such as precipitation, temperature changes, etc., which must most probably occur.

For the processes of identification and delimitation of air masses, we require the determination of all the important conservative or semi-conservative qualities or attributes to be found in the atmosphere, such as specific humidity, potential temperature, equivalent potential temperature, and the like. These attributes of each respective type of air mass permit us to put a labeling tag, so to speak, upon each air mass and allow us to recognize a given air mass through the course of its vicissitudes. By means of continuous or periodic observations of the proper sort, we may note the progressive changes which occur. In order to satisfactorily describe and understand the nature of these changes, it is necessary for us to employ dynamically significant criteria. That is, it is not sufficient for us merely to study such directly observable quantities as pressure, temperature, and relative humidity, but we must also study quantities which may be computed in terms of those just mentioned and which have been deduced by means of mathematico-physical reasoning along the lines of dynamical meteorology from a minimum of suitable premises. The importance of this approach is seen in the fact that physical weather analysis on this basis will lead to a verification or disproval of the premises underlying the derivation of the relationships which are expressed numerically by the quantities in question. Thus, the outcome of this mode of attack will be a more nearly exact knowledge of the dynamics of the atsmosphere which is so essential to the elevation of weather forecasting from the present semi-physical methods to the desired mathematico-physical methods so successful in other fields.

We may now return to the question of how a commercial pilot may contribute to a program of air-mass analysis by observations made during flight. Observations made from a commercial airplane with the ordinary equipment carried thereon are of course limited in scope; however, worthwhile results may be so obtained. The main objectives in such cooperative effort would be:

1. The location of surfaces of discontinuities and fronts in space and time, with description of conditions on both sides of the discontinuities.

2. Determination of vertical motion in the atmosphere when detectable, and observation of accompanying phenomena.

3. Observations of conditions during occurrence of various phenomena such as icing of airplanes, development of clouds from a three-dimensional aspect over a period of time, etc.

For every phenomenon reported by a pilot there should always be given the following data:

(*a*) Geographical position (with respect to known towns or cities; or latitude and longitude).

(*b*) Date.

(*c*) Time of day (and standard meridian time used).

(*d*) Altimeter reading, expressed as height above sea level or above some specified point.

(*e*) The barometric pressure at which the altimeter would read zero altitude; place and time of take-off; temperature at surface at time of take-off.

(*f*) Temperature of the free air, read from a strut thermometer, at point of observation of phenomenon.

(*g*) General weather conditions at time of observation, including: Cloudiness—amount, kind, and heights of bases and tops of various cloud formations, if determined; precipitation—kind, intensity, greatest and lowest heights at which observable.

Some observations which are of assistance in attaining the first objective, viz, the location of surfaces of discontinuity and fronts, follow:

1. *Discontinuities in atmospheric turbidity, i.e., surfaces across which marked changes in turbidity are observable.*—(*a*) Haze layers; (*b*) dust layers; (*c*) tops and bases of stratiform clouds; (*d*) top of fog, etc.; giving in each case the cause of the turbidity, its thickness, horizontal extent, visibility, and measure of turbidity expressed preferably in some such scale of opalescent turbidity [1] as Bergeron has given in his well-known work, Über die Dreidimensional Verknüpfende Wetteranalyse, I, Geofysiske Publikasjoner, vol. V, Oslo, 1930.

2. *Thermal discontinuities.*—The airplane should carry a strut thermometer to detect such discontinuities. Due to various difficulties only inversions of temperature (i.e. increase of temperature with height) are easily detectable by means of a strut thermometer. Fronts also may be easily detectable thereby.

3. *Humidity discontinuities.*—Commercial airplanes usually are not equipped to measure relative humidity.

4. *Wind discontinuities.*—Marked shifts in wind direction, and rapid changes in speed with change in height or change in horizontal position are observable from mechanical effects on the flight of the airplane or from changes in the drift of the ship when the ground is visible. Squalls and wind-shift lines such as are encountered near cold fronts and in connection with thunderstorms, come under this heading.

As for the second objective mentioned above, there may be observed:

1. *Bumpiness.*—Bumpiness may be reported on a scale of 0–5, such as was given by W. H. Pick and G. A. Bull in Great Britain Meteorological Office Professional Notes No. 46, "A Note on Bumpiness at Cranwell, Lincolnshire," 1927; 0, no bumps; 1, slight bumps; 2, occasional bumps; 3, bumpy; 4, very bumpy; 5, exceptionally bumpy. Horizontal extent, nature of the terrain and accompanying phenomena, if noticeable, should also be given.

2. *Marked upward and downward large scale currents.*—These are most pronounced in spring and summer and usually in connection with cumulus and cumulo-nimbus clouds (thunderheads). Also with the squall-line attending cold fronts. Such currents are detectable by rapid vertical cloud motions and by differences in climbing or gliding speeds from the normal for the given flying conditions.

The third objective given above applies to miscellaneous phenomena, e.g.:

1. *Icing of airplane.*—Ice which accumulates on airplanes should be classified as (*a*) hard ice; (*b*) rime; (*c*) frost. Hard ice is essentially the same as glaze; however, it may be either clear or opaque (whitish). The thickness, physical appearance, place of formation, temperature of air, visibility in cloud (or rain) where formation occurred, rapidity of formation, etc., should also be given.

2. *Development of clouds.*—The aviator can frequently observe details in regard to the growth or disappearance of clouds not easily obtainable from ground observations. Such information may possibly be of value in the final analysis of what processes actually cause condensation of water vapor into clouds and subsequent precipitation.

In conclusion, it would appear feasible to prepare printed forms on which commercial pilots could indicate the pertinent phenomena observed during flights, and to develop a system whereby the pilot would turn in these reports to local weather observers at airports who would then forward them to the proper headquarters where studies would be made of the accumulated data. Such a cooperative effort might conceivably be of inestimable value in the long run to both parties concerned by virtue of the enhancement of our knowledge of the atmosphere and the improvement in forecasts.

The synopsis of weather analysis given earlier in the paper represents the consensus of opinion of officials at the Central Office of the Weather Bureau.

[1] The purpose of determining the opalescent turbidity is to obtain an approximate measure of the amount and fineness of the suspended solid material in the atmosphere which because it settles out so slowly is a semiconservative characteristic of air masses in general. A measure of the opalescent turbidity is, roughly speaking, a measure of the light-scattering power of the exceedingly fine solid particles which are suspended in the atmosphere. This measure is approximately inversely proportional to the visibility, provided that the observations of the latter are made so as to be independent of the distance, color, brightness, and albedo of the object viewed; the position of the sun with respect to the line of sight; the cloudiness; the color, brightness, and albedo of the sky and background, etc. To attain this end in a practical manner, Bergeron has laid down rules for selecting suitable objects, with instructions for making observations of visibility so that one may thus obtain a measure (approximate) inversely proportional to the opalescent turbidity. In this scheme, distant mountains and elevated objects are considered most suitable, provided that in making the scale of visibility the respective objects subtend equal angles at the eye of the observer no matter what their distance. The objects should not extend too high if it is desired to measure the horizontal visibility. The objects *must* be dark, preferably black. White objects, water, and brightly colored structures are precluded. Objects should not be viewed toward the sun, but preferably at right angles to the line from observer to sun, and not in twilight. Also, not under low thick clouds or fog, especially if the sky is largely clear. The nature and color of the objects so viewed, the relative positions of the sun, observer, object, and cloudiness, whether the object was shaded from the sun and sky largely clouded over, whether the object was illuminated and the sky largely clear, or whether other conditions prevailed in this respect, clarity of the details and contour of the object viewed, etc., should be stated with each observation; also any coloration observed due to the turbidity itself. (See also H. Koschmieder—Theorie der horizontalen Sichtweite, Beiträge zur Physik der freien Atmosphäre, Band XII, 1925, pp. 33–55, and 171–181.)

A STATISTICAL ANALYSIS OF FOGS AT GREENSBORO, N.C., AIRPORT

By JOHN C. SCHOLL

[Angier, N.C., May 1934]

During the 4-year period, August 1929 to July 1933, inclusive, fog occurred at the Greensboro Airport 381 times. Of this number 4 began as dense and ended as light, 1 was dense from start to finish, 116 began as light but were dense some time, while the remaining 260 were light all the time. The average number per month of light and dense fogs for this period was 7.9 and 2.5, respectively.

Each of these 381 cases was, of course, the result of either general or local meteorological changes. The general conditions and changes favorable to fog are well known. However, many of these fogs unquestionably occurred as a result of purely local changes, some of which were probably very slight and seemingly insignificant. Consequently the results of this study are not entirely representative of the conditions which exist in any locality other than the Greensboro Airport.

Figure 1 substantiates the general opinion that both light and dense fogs are more prevalent in the winter months. It is believed that if data were available for a